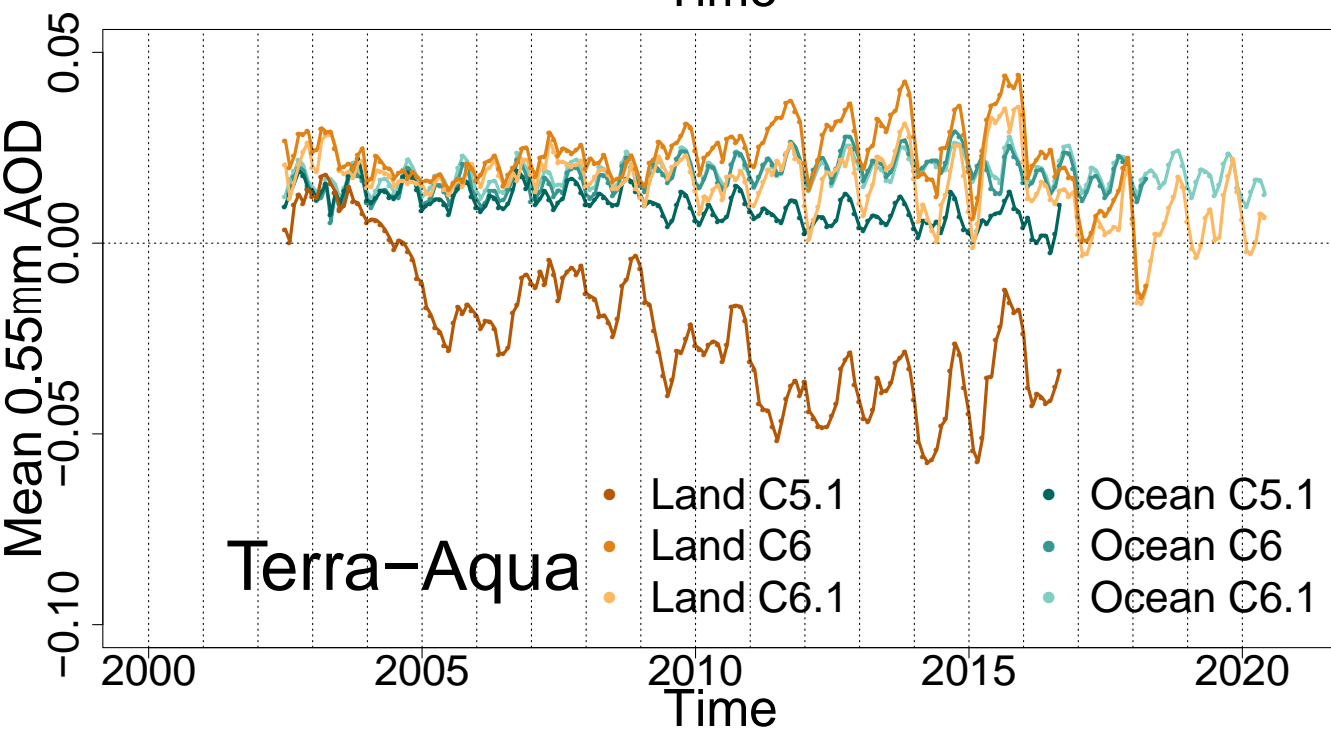
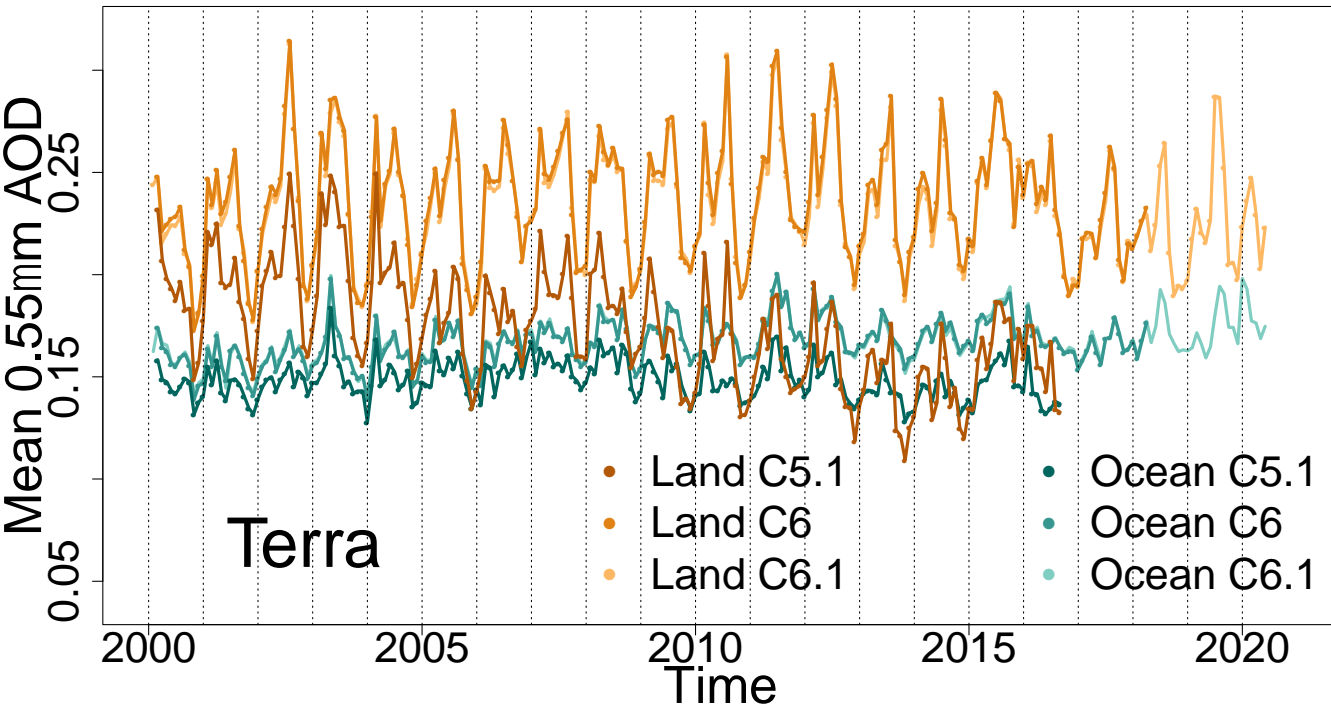


Trends and continuity in the AOD record for MODIS, VIIRS, and GEO sensors

Virginia Sawyer, Rob Levy

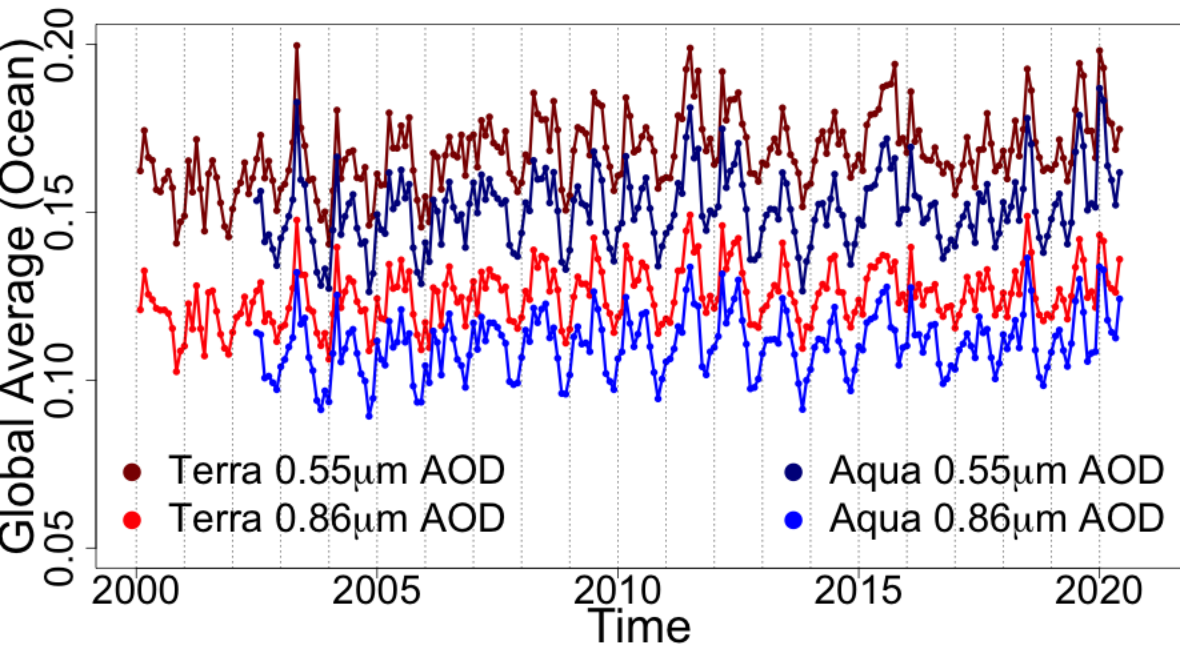
MODIS/VIIRS Calibration Workshop

Feb. 26, 2021

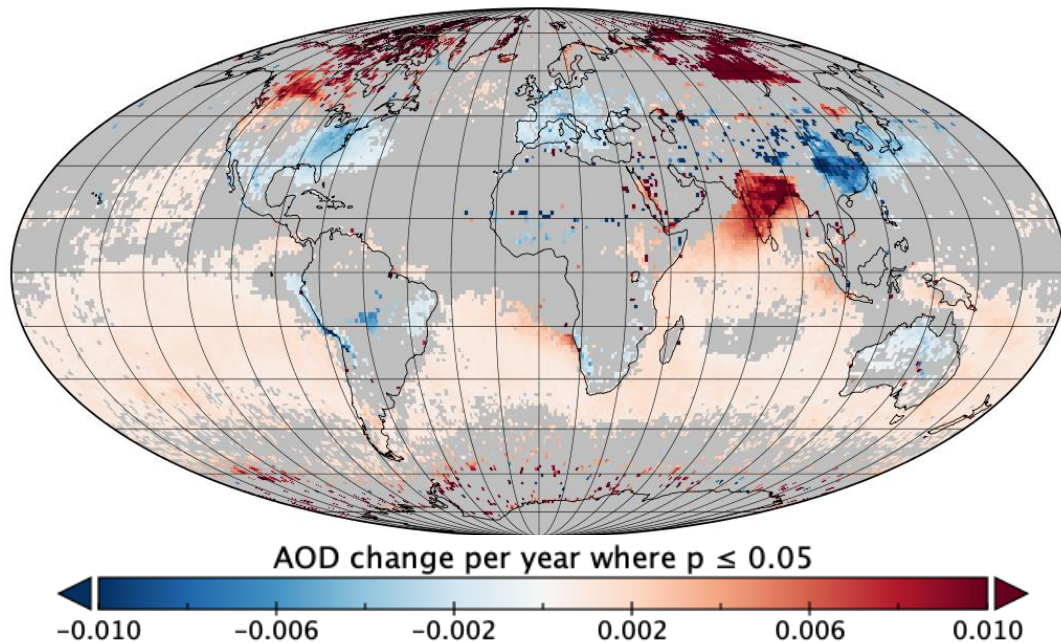


Global average AOD Collections 5.1-6.1

- Offsets in Terra-Aqua AOD have decreased and become more constant with successive MODIS collections
- No more multi-year trends. Global average AOD changes seasonally, but not significantly over the 20-year MODIS mission
- This is thanks more to updates to L1b reflectances than to changes to the Dark Target algorithm itself
- Small offsets in L1b reflectances ($\pm 2-3\%$) lead to larger offsets in AOD ($\sim 10\%$)



Terra AOD Trend, 2000-2020

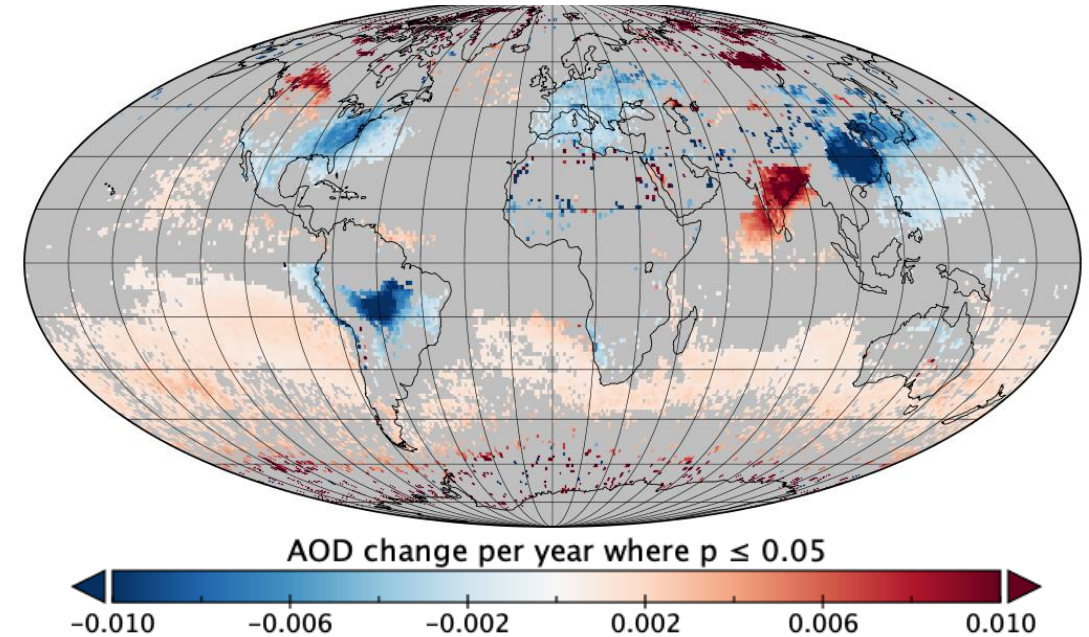


Multiple wavelengths and regional trends

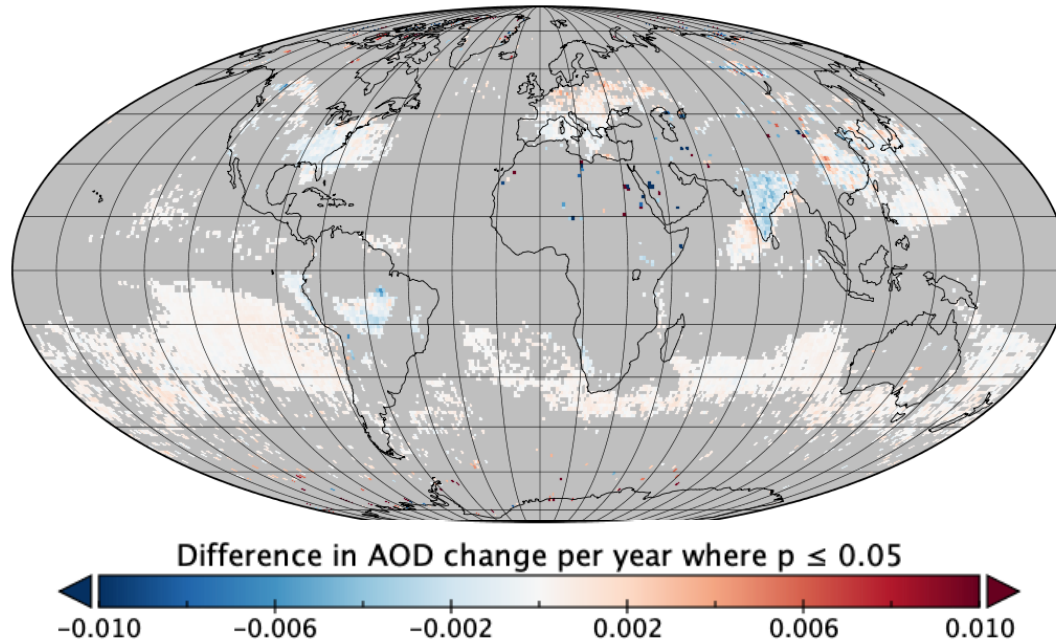
- Terra-Aqua offsets can vary by wavelength, which affects Ångström exponent and any other measure that compares multiple bands
- Lack of a trend on the global average does not mean there are no regional AOD trends
- Reductions in industrial and urban emissions over the last 20 years are almost exactly balanced by increases in AOD elsewhere
- Do Terra and Aqua agree?

- Linear regression of monthly average AOD since Aqua mission began, June 2002 – June 2020
- Trends are calculated for each L3 $1^\circ \times 1^\circ$ grid cell and plotted only if significant ($p \leq 0.05$)
- Difference in trends between Terra and Aqua is plotted only if *both* show a significant trend, but the two sensors broadly agree

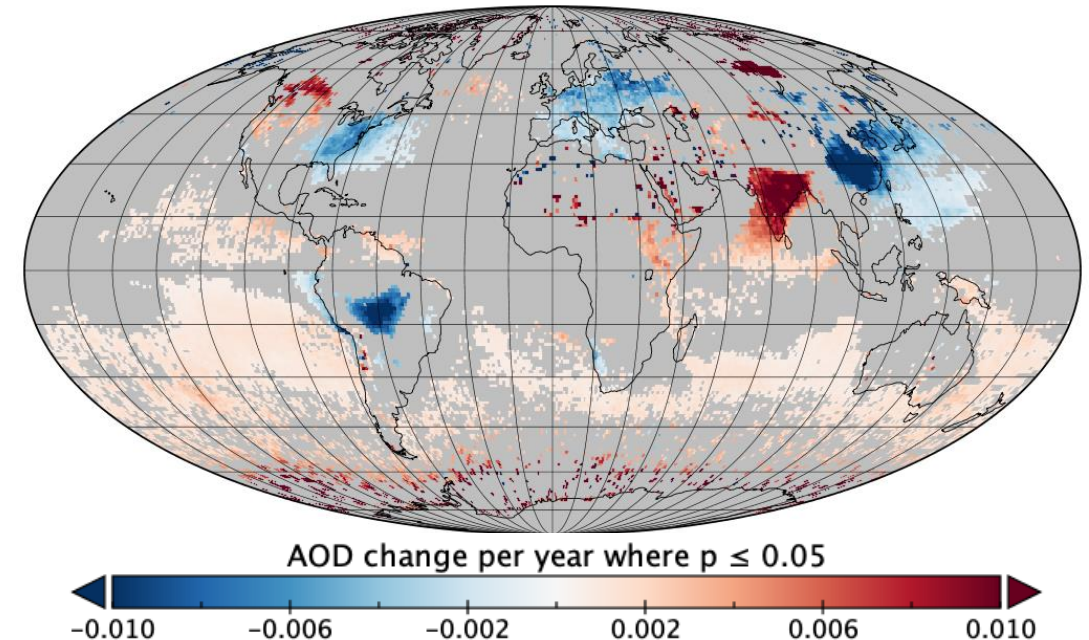
Terra



Terra - Aqua

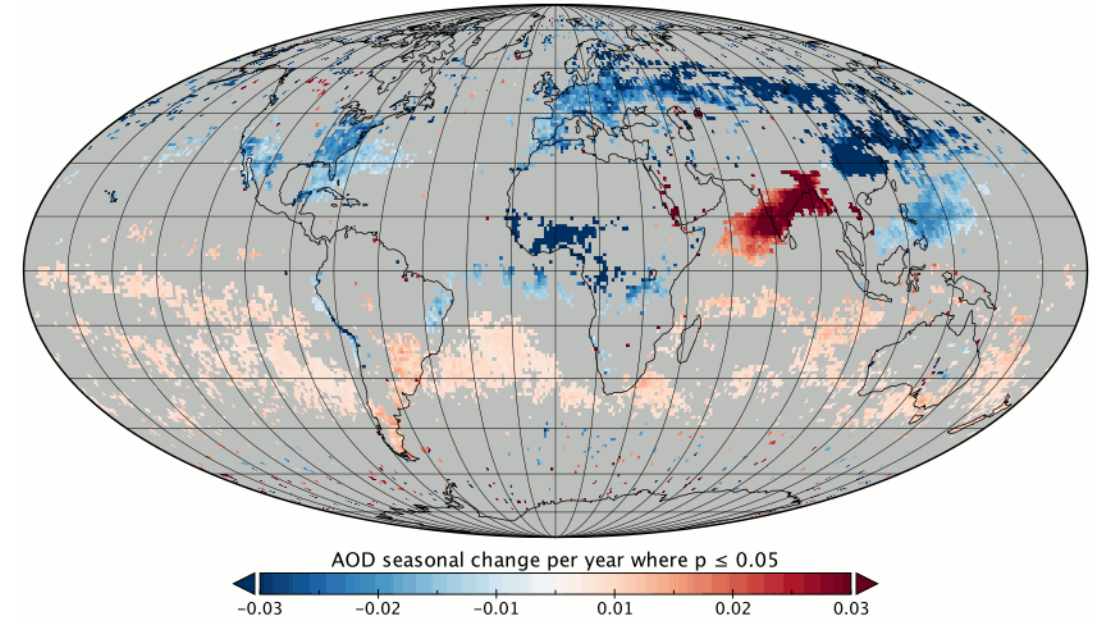


Aqua

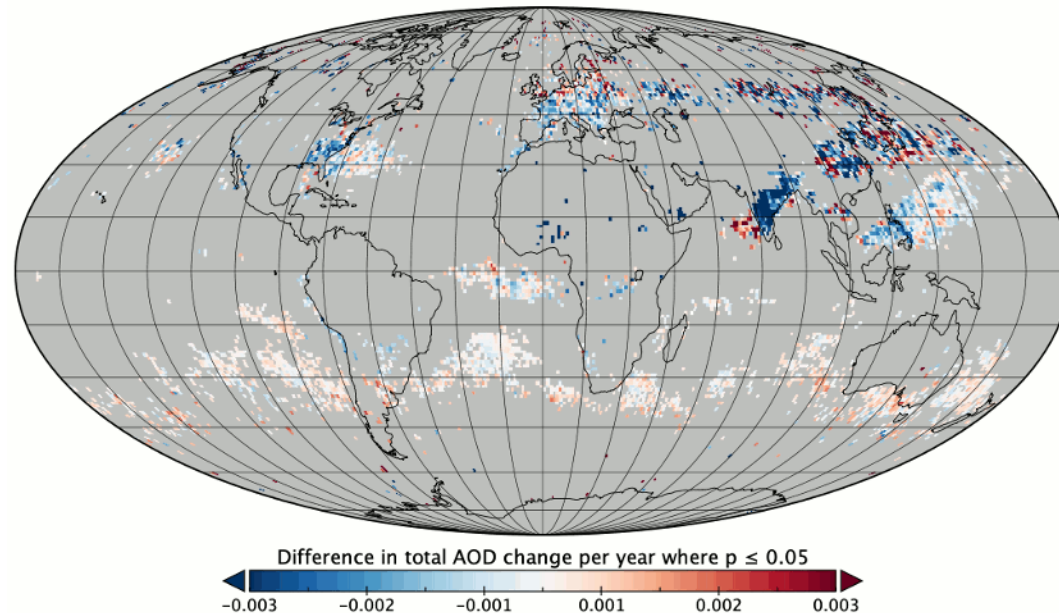


- Decrease over eastern North America, Southeast Asia, and Europe in spring and summer coincides with emissions reductions to improve air quality
- Increase over India and outflow region peaks in fall and winter and coincides with an increase in agricultural burning
- Cause of widespread increase in AOD over the Southern Hemisphere oceans is unknown

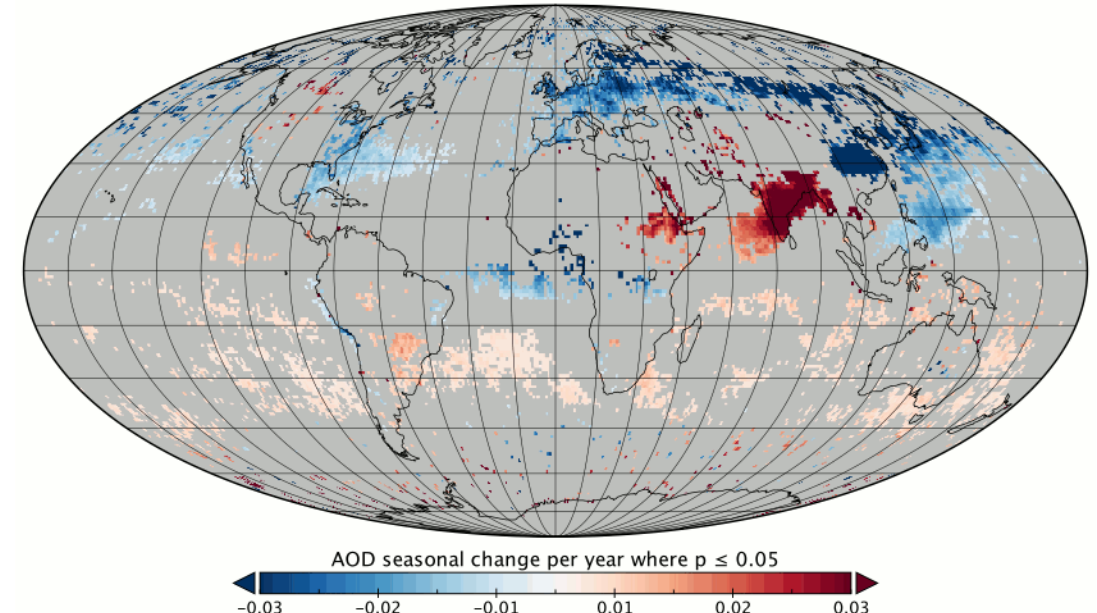
Trend in 0.55 μm AOD, Terra, 2002–2020 MAM



Difference in AOD Trend, Terra – Aqua, 2002–2020 MAM

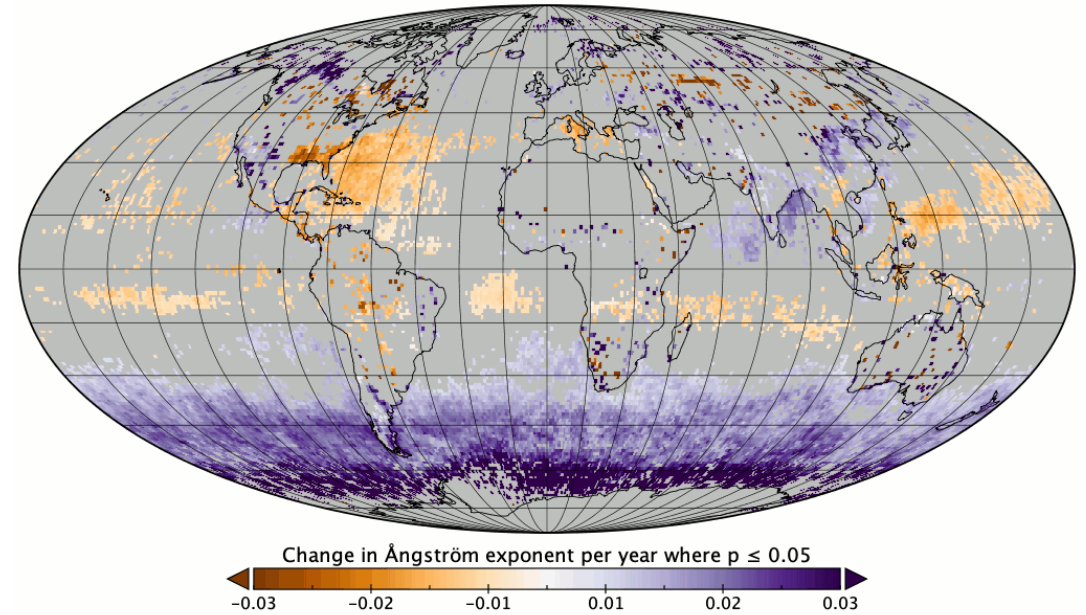


Trend in 0.55 μm AOD, Aqua, 2002–2020 MAM

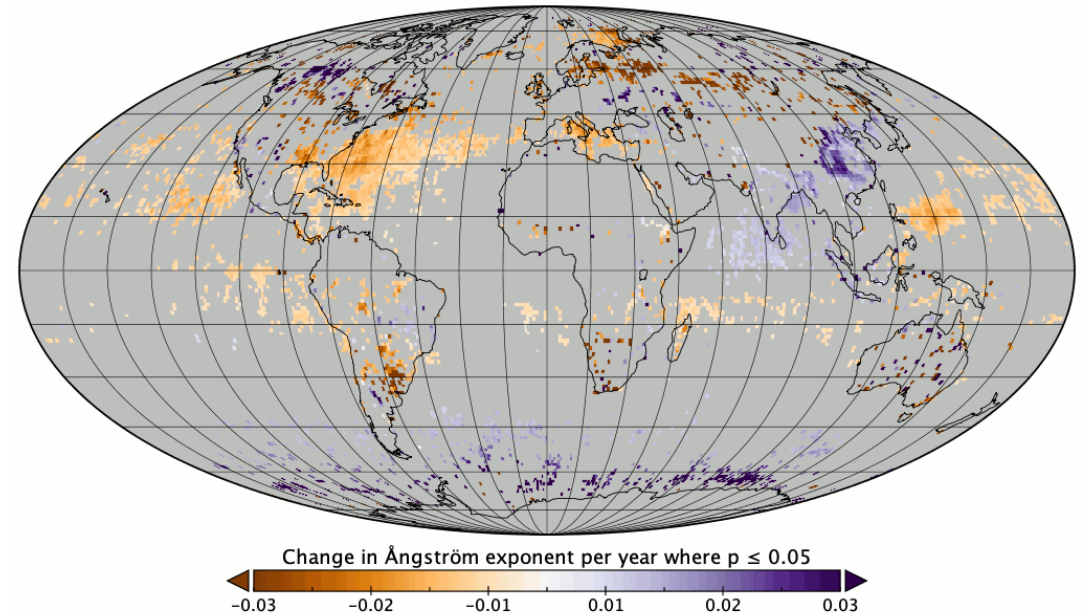


Regional trends in Ångström exponent

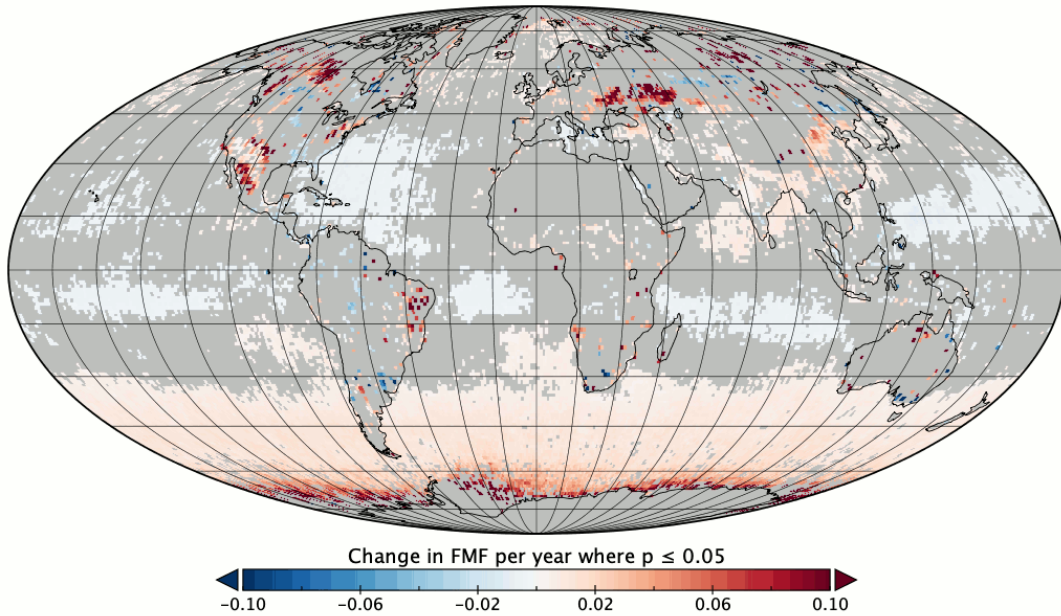
- Ångström exponent is based on the ratio between AODs at $0.55\ \mu\text{m}$ and $0.86\ \mu\text{m}$ over ocean, and $0.47\ \mu\text{m}$ and $0.66\ \mu\text{m}$ over land
- Trends would imply that particle sizes are increasing (orange, “dustier”) or decreasing (purple, “smokier”) over time, and could mean a change in aerosol composition or sources
- This time Terra and Aqua show major disagreement, especially over ocean
 - Aqua shows few significant trends but mostly decreased AE over tropical oceans
 - Terra shows much more widespread trends, especially strong increases in AE over high latitude oceans (only measurable in summer)



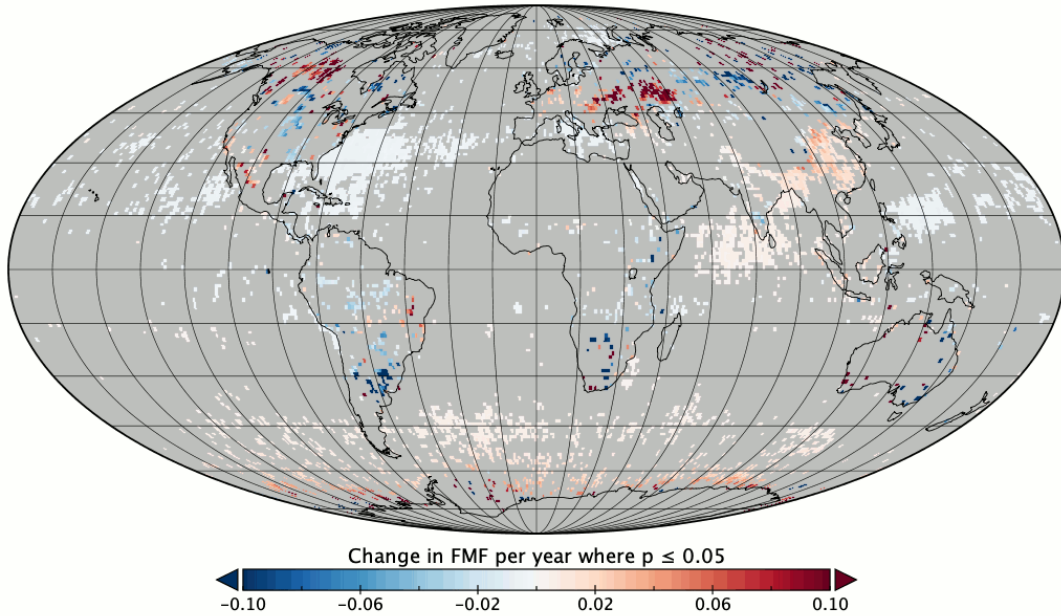
Ångström Exponent Trend, Aqua, 2002–2020 MAM



Fine Mode Fraction Trend, Terra, 2002–2020 MAM



Fine Mode Fraction Trend, Aqua, 2002–2020 MAM

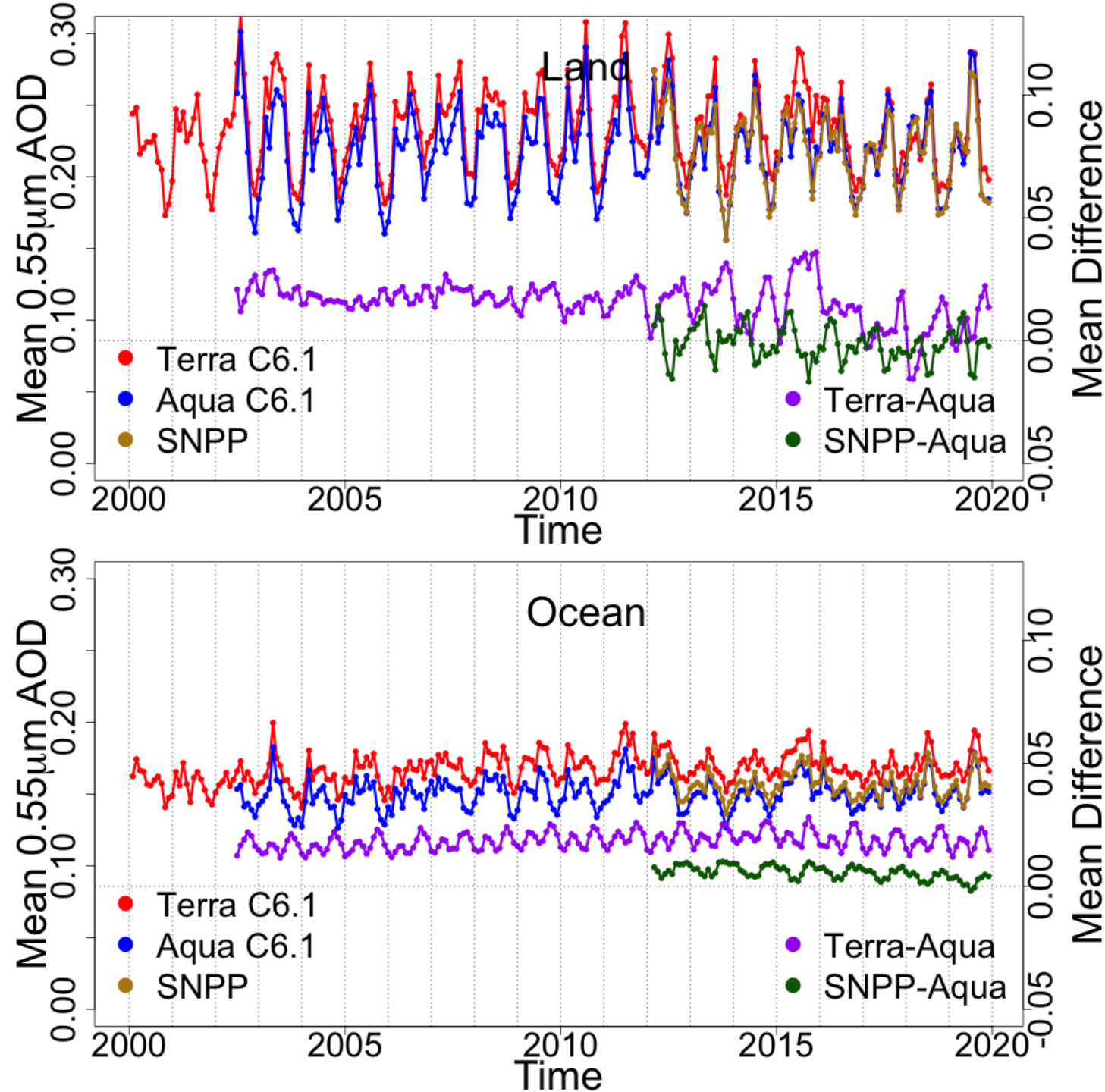


Regional trends in fine mode fraction

- Fine mode fraction is derived from the Dark Target aerosol model solutions, but has similar patterns to Ångström exponent trends:
 - Terra shows an increase in fine mode aerosols in the high latitude oceans
 - Aqua shows few grid cells with any significant trend, but some decrease in fine mode aerosols over tropical oceans
- Very high edge values may be due to limited sampling at extreme latitudes
- Why do they disagree? Which trends are real?
- Terra and Aqua are not our only sources for Dark Target data...

Adding VIIRS SNPP to the Climate Data Record

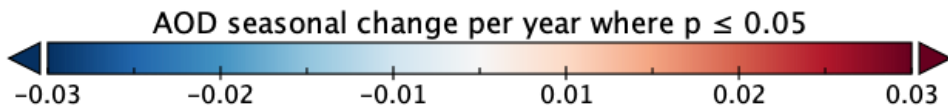
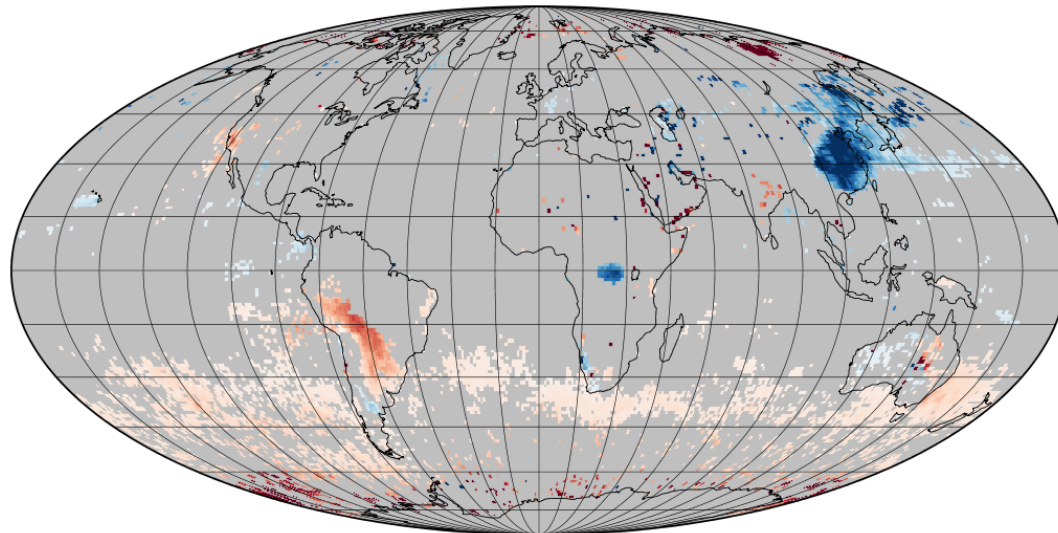
- Dark Target ported to SNPP VIIRS is now on Worldview and LAADS, updated to version 1.1
- AOD offsets between SNPP and Aqua are smaller than those between Terra and Aqua
- Upcoming VIIRS NOAA-20 product will further extend the AOD satellite climate data record, but will also come with its own offsets
- Which one is “true”? Users who need a single unbroken data record may choose to transition from Aqua to NOAA-20, and adjust the others to match



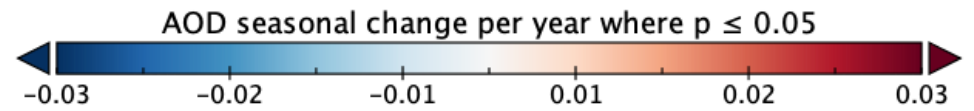
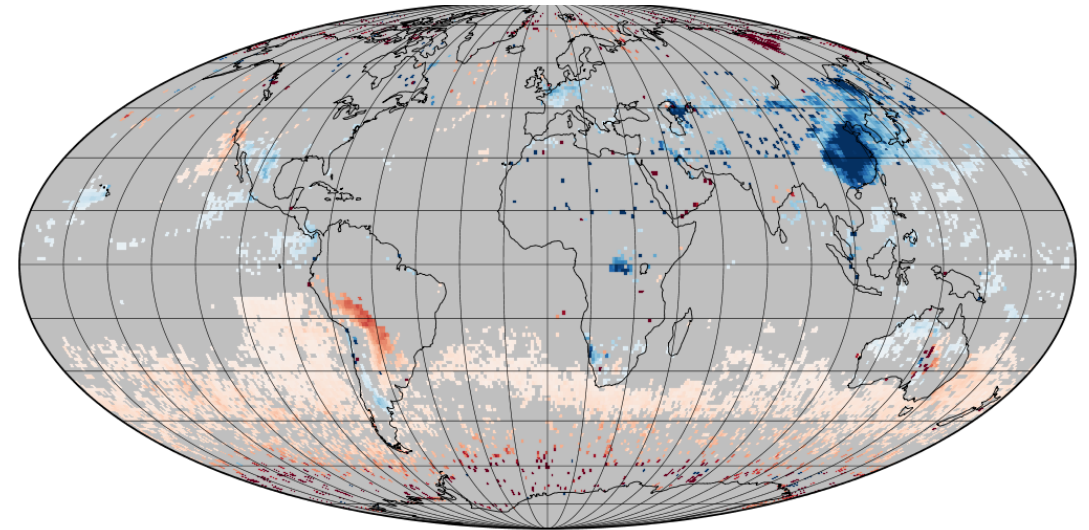
Regional trends in VIIRS SNPP AOD, 2012-present

- Trends from 2012-2020 are not the same as from 2002-2020, and shorter records mean fewer significant grid cells
- However, SH ocean and Southeast Asia show similar trends to the longer record, implying these changes are relatively steady

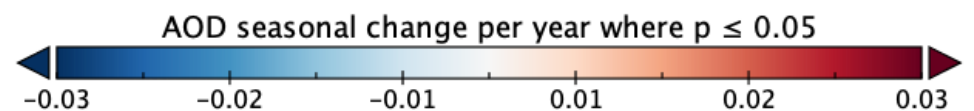
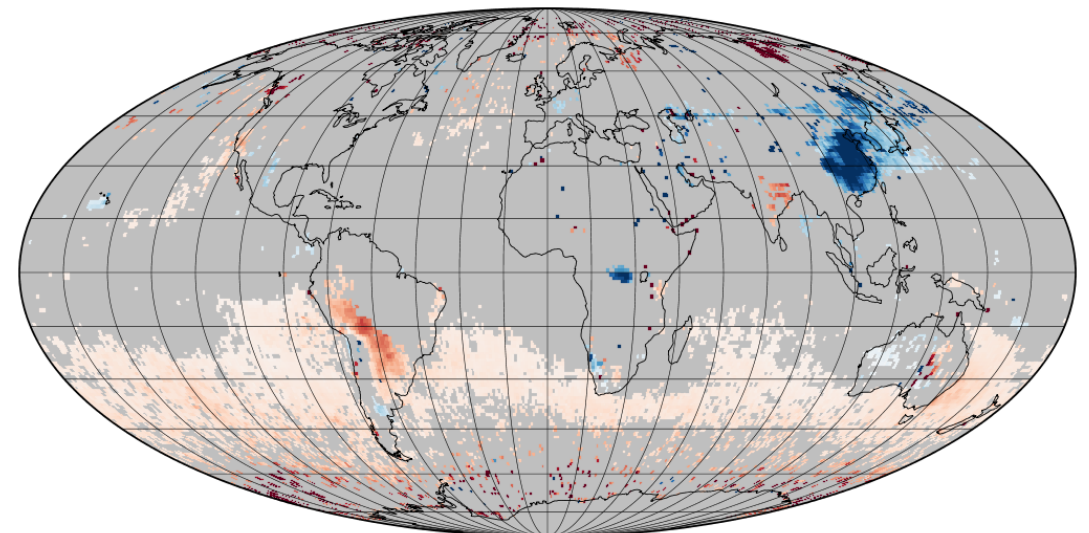
VIIRS SNPP



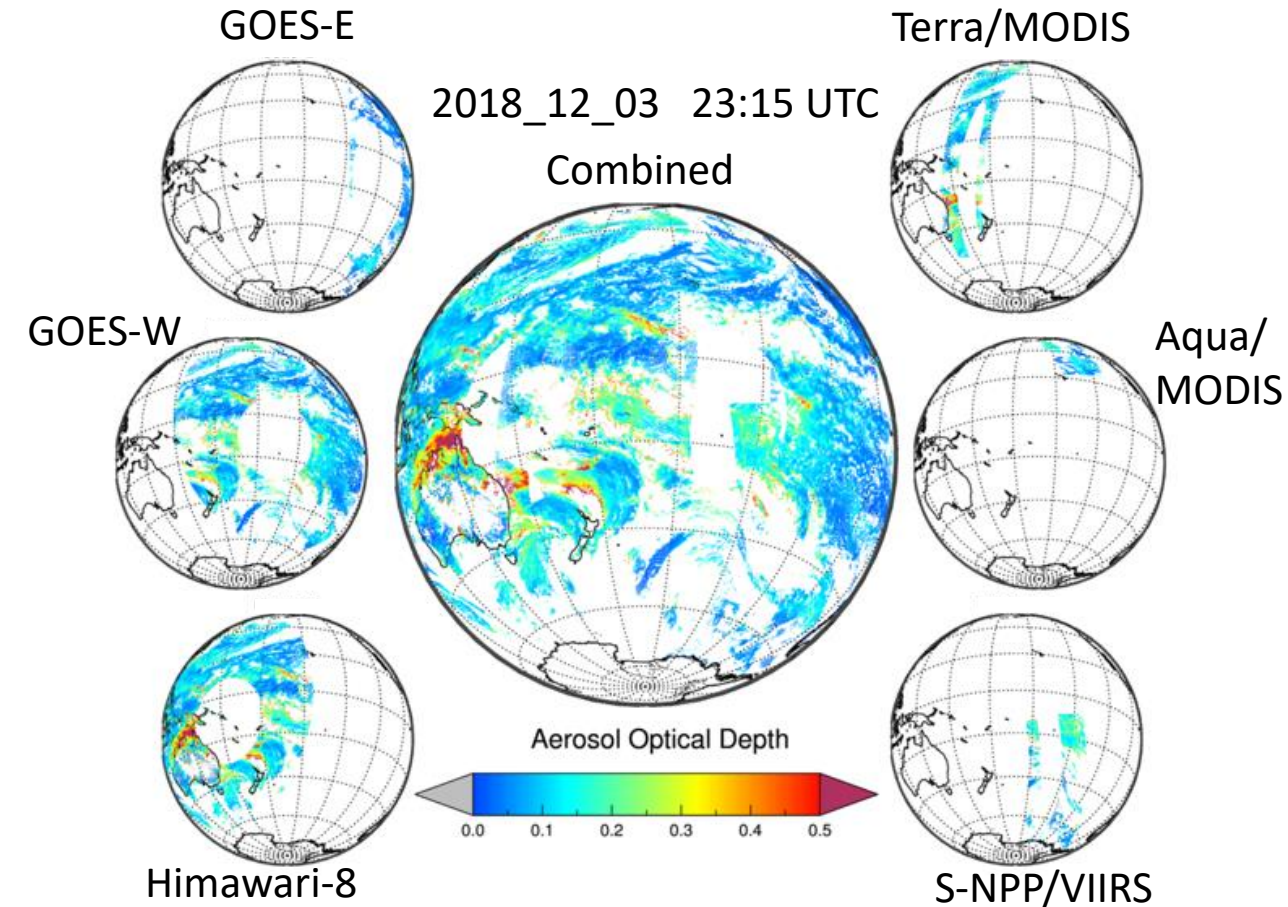
Terra



Aqua



Dark Target for more sensors



- VIIRS NOAA-20 version is in development, and the same process will work for future VIIRS launches
- Dark Target ports for the geostationary imagers aboard Himawari-8, GOES-E, and GOES-W
- Geostationary Dark Target is capable of capturing the aerosol diurnal cycle, and opens the possibility of multi-sensor joint retrievals
- Combined product is gridded $0.1^{\circ} \times 0.1^{\circ}$, must account for different instrument resolutions and measurement intervals

Summary and further questions

- Terra, Aqua, and SNPP roughly agree that while globally averaged AOD does not show multi-year trends, there are significant regional trends
 - Over land, they appear to match what we know of changes in air quality
 - Over ocean in the Southern Hemisphere, a slow but widespread increase in AOD needs to be explained
- Terra and Aqua disagree on whether particle size is changing, particularly in the SH ocean
 - Terra sees an increase in fine mode aerosol, but Aqua sees no significant change
 - Why do they agree on total AOD, but not on Ångström exponent or fine mode fraction?
 - Both are physically plausible, but we need more information
- VIIRS SNPP, geostationary imagers, and eventually NOAA-20 and future VIIRS have Dark Target ports with their own sources of data, albeit much shorter data records so far
- Each new sensor will have its own offsets and sources of trend disagreement